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# *Estimating a Research and Development Price Index*

*Michael A. Shires*

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*Michael A. Shires*

*Prepared for the*
*Under Secretary of Defense for Acquisition*

**National Defense Research Institute**

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## PREFACE

This document was prepared as part of a project to review current and prior methods of deflating out-year military research and development spending and to develop improved deflators for that purpose. The work reported herein represents the second stage of three included in the overall project. The study should be of interest to policymakers in the Department of Defense and the Congress.

This research was conducted for the Under Secretary of Defense (Acquisitions) within the International Economic Policy Program of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense and the Joint Staff.


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## SUMMARY

This document describes the development of an alternative price deflator that would more appropriately reflect the actual changes in prices in the research and development (R&D) process. The objective is to identify those sectors of the economy where R&D occurs and to identify the price changes that occur within those sectors.

This process is accomplished with detailed information describing the component sectors of R&D activity published by the Institute for Defense Analysis. This information is then coupled with the changes in prices reflected in those specific industries or, when specific data were not available, the nearest available proxy. In the case of one major component, several proxies are used to test the sensitivity of the result to the proxies used. This information is then aggregated into a set of composite R&D deflators for each branch of the service and composite R&D deflators for overall defense R&D expenditures.

The results of this process are surprising. The resultant R&D indices closely parallel the Gross National Product (GNP) deflator. There is some variability in the series, however, depending upon which proxies are used. The overall result is that the price series derived herein for R&D expenditures are generally close enough to the GNP deflator that, in the interests of parsimony, and subject to the caveats specified in this analysis, the GNP deflator is a reasonable index to use to value out-year research and development expenditures.

## ACKNOWLEDGMENTS

I would like to acknowledge RAND colleagues Charles Wolf, Jr., and Loren Yager for their assistance in the execution and design of this study. The comments of Peter J.E. Stan were also invaluable in the preparation of this report.

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| BLS | Bureau of Labor Statistics |
| CGM | Complete Guided Missiles |
| CPI | Consumer Price Index |
| DRI | Defense Research Institute |
| FY 1986 | Fiscal Year 1986 |
| GNP | Gross National Product |
| PPI | Producer Price Index |
| R&D | Research and Development |
| RDT&E | Research, Development, Testing, and Evaluation |
| SIC | Standard Industry Classification |

# 1. INTRODUCTION

The modern budgeting environment is a complex and dynamic place. One of the primary complicating factors in the annual budgeting process is the effect of changing price levels. This concern over inflation has led to the development and use of a variety of price deflators. Some common deflators include the Consumer Price Index (CPI),[1] the Producer Price Index (PPI),[2] and the Gross National Product (GNP) deflator.[3] These indices attempt to reflect current prices for a good in terms of a base-year price for the same or comparable good.[4]

The budgeted expenditure stream is weighted by these deflators to ascertain the anticipated *real* effects of changes in the budget stream. For example, suppose that a budget of $100 million in year 1 is maintained at $100 million in year 2, while inflation (which represents the costs of goods and services) simultaneously rises at 5 percent. Although the budget level has not changed in current dollar terms, the quantity of real goods and services that can be purchased by the budgeted amount has decreased, resulting in a reduction in the real budget.

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[1]The Consumer Price Index is a weighted average of the relative change in prices for consumer goods maintained by the Bureau of Labor Statistics. It attempts to measure changes in the cost of living for a typical U.S. household.

[2]The Producer Price Index is another measure of the changes in prices, but this time of the weighted costs of inputs into production for specific products. The PPI is organized by Standard Industry Classification (SIC) Codes and accumulated by the Bureau of Labor Statistics.

[3]The GNP deflator is an aggregate statistic compiled by the Bureau of Economic Analysis that reflects the change in aggregate production prices within the economy.

[4]Suppose a widget costs $1.00 in year 1, $1.20 in year 2, and $1.56 in year 3. A price index in year 1 prices would indicate 100.0 for year 1, 120.0 in year 2, and 156.0 in year 3. The calculation is derived by dividing the price in year x by the price in the base year and multiplying by 100. The general form is given by:

$$\text{INDEX}_{\text{Year 1}} = \frac{\text{PRICE}_{\text{Year 1}}}{\text{PRICE}_{\text{Base Year}}} \times 100$$

In preparing its annual budget, the Department of Defense takes into account the effects of inflation on program budgets. This is done by deflating each budget entry, including the budget for research, development, test, and evaluation (RDT&E), over time by the GNP deflator. This is the motivating action behind developing an alternative deflator.

There is some concern that the GNP deflator, which is a broad measure of changes in prices across the economy, may not adequately or accurately reflect the changes in prices that occur within the sectors of the economy where RDT&E primarily occurs. To address this concern, the Department of Defense has commissioned a study to evaluate the alternative approaches to estimating these price changes. As part of that effort, this document develops an alternative deflator for RDT&E activities.

Section 2 details the methodology used to derive the alternative deflator; Section 3 presents the resulting research and development deflator and compares it to some other leading indicators.

## 2. METHODOLOGY

The objective of this analysis is to generate a set of composite indices that reflects the price changes within the research and development-related sectors of the economy. This process entails three tasks: (1) identify the appropriate R&D-related sectors; (2) identify the relevant changes in prices in these sectors; and (3) combine this information into a set of aggregate composite research and development indices.

### STEP 1. IDENTIFYING THE RELEVANT SECTORS

The first stage of the process is to identify the sectors in which defense research and development expenditures occurred. Chapter 6 of *The Revised Defense Translator*[1] contains this information for Fiscal Year 1986. Tables VI-3, VI-4, VI-5, and VI-6 in that chapter provide vectors detailing the RDT&E expenditures for the Army, Navy, Air Force, and Defense Agencies[2] respectively, distinguished by Defense Research Institute (DRI) Industry Codes.

A general consideration related to these vectors is that the majority of expenditures are concentrated in a relatively small number of categories. For parsimony's sake, this analysis will concentrate only on those components that represent more than 3 percent of the total vector. These component vectors are presented in Appendix A, Table A.1. As can be seen from Table A.1, these categories make up a very significant portion of the overall vectors. All other categories in the vectors have been aggregated into the "Other Categories" total.

It is important to recognize that these vectors were generated from exhaustive analysis by the Institute for Defense Analysis, which mapped appropriations for each branch in FY 1986 to SIC and DRI codes. In

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[1]Thomas P. Frazier, Carol G. Campbell, and Richard T. Cheslow, *The Revised Defense Translator*, Institute for Defense Analysis, Alexandria, Virginia, IDA Paper P-2141, October 1989, pp. VI-1 to VI-9.

[2]The "Defense Agencies" category includes all of the non-service Department of Defense agencies, such as the Defense Intelligence Agency, Defense Mapping Agency, and the Defense Logistics Agency.

addition to the standard object classifications, contracts were individually mapped into the appropriate classifications through the use of the Prime Contract Awards data base.

A relevant issue for these vectors is that they include only FY 1986 data and hence may not necessarily be applicable to all possible years. This analysis spans the ten-year period 1981-1990, and it is conceivable that the sectoral composition of RDT&E expenditures varied somewhat during this period. For the purposes of this analysis, however, it is assumed that FY 1986 is a representative year for RDT&E expenditures.

**STEP 2. IDENTIFYING CHANGES IN RELEVANT SECTOR PRICES**

Once the appropriate R&D-related industry sectors have been identified, it is necessary to identify the relevant measures of price changes in these sectors. Because many of these sectors are clustered in the manufacturing sector, a readily available measure of these price changes is found in the PPI.

PPI statistics for many goods are accumulated by the Bureau of Labor Statistics (BLS) and published on a monthly and annual basis. The PPI, as described above, identifies changes in the costs paid by producers for the raw and intermediate good inputs into their production processes. These statistics represent a useful measure of general price changes within their specific sectors. There are, however, some limitations associated with using these statistics that must first be discussed to provide an overall context for the methodology.

**Some General Considerations**

One purpose of this analysis is to assess whether any significant difference exists between price changes in the overall economy (as indicated by the GNP deflator) and price changes in those economic sectors where R&D activity specifically occurs. There are no specific statistics that measure price changes exclusively in R&D activity in these sectors and, due to the inherent objective of R&D to produce

improvements in outcome quality, these statistics would be difficult, at best, to accumulate.[3]

Framed in this context, there are at least three significant additional limitations to applying these statistics in the case of this particular study. First, the BLS does not accumulate PPI statistics for many of the SIC codes to which the categories specified in the vectors in Table A.1 map. This necessitates the use of proxies in those cases where the values do not map directly.

Second, the series that are available do not span the entire ten-year period addressed by this study. Many of the relevant PPI series were initiated in 1985. This necessitates the occasional use of proxies for the early years of some of the index series used in this analysis.

The third limitation is related to the service components of the vectors. PPI data are limited for the services sectors of the economy and are concentrated primarily in transportation and utilities. Because of this paucity of data, the CPI is used below as a proxy. The primary difference between the CPI and the PPI is that the CPI is a consumer-oriented index. It contains not only price increases for the inputs, but also changes in retail margins and the nature of the marketplace. For manufactured goods, this would certainly be problematic. For services, however, these effects may be minimized. Prices for services are typically priced as multiples of the input costs, typically labor.[4] As long as this multiplier remains constant over the period in question, changes in consumer costs will reasonably reflect changes in the costs of the inputs for services.[5]

Another limiting aspect of using the CPI as a proxy for the PPI is that individual consumers and businesses face very different cost profiles. Individuals, for example, may expend considerably more

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[3]This derives from the fact that price indices attempt to estimate changes in the prices, keeping all other factors (including quality and quantity) constant.

[4]Law and accounting firms, for example, typically bill clients at a rate that represents three to four times their labor costs.

[5]While this approach does not account for the effects of capital-related increases in productivity in the service sectors, the literature is very mixed as to the scope and validity of any such productivity increases.

resources on rent and transportation services than businesses, whereas business service expenditures may lie in the professional services areas, such as legal, accounting, and medical services.

Having framed the analysis in this contextual framework, the focus can now be directed toward the methodology used to derive the alternative R&D deflators. Although there are certainly limitations on the assumptions used in this analysis, the derived deflators can provide insights into the specific applicability of the GNP deflator to R&D appropriations.

**Identifying Price Changes**

Each of the sectors identified in Table A.1 corresponds to a DRI industry category, which in turn generally corresponds to an SIC Code. These vector values were mapped to their corresponding industry codes for reference in ascertaining the price behaviors in each individual R&D-related industry sector (see Step 2 below).

The next stage of this analysis is to identify price changes in the R&D-related sectors identified in Step 1. To accomplish this task, an attempt was made to identify PPIs for the relevant sectors mapped in the vectors. Unfortunately, PPI data for the sectors that map directly to the DRI codes are not consistently available. Accordingly, each component of the vectors has to be treated on a case-by-case basis.

**Detailed Methods for Identifying Price Changes**

In the following subsections, the specific indices or proxies used to characterize price changes and their specific origins are identified. For all of the PPI references in this report, the data were culled from the Producer Price Indices as reported by the Bureau of Labor Statistics. The PPI values represent the average annual PPI indices published in the annual data summaries from 1984 to 1990. For 1981 to 1983, the annual summaries were not available, so the PPI value used represents the value reported in the October monthly report.[6]

[6]October was selected because it represents the first month in the federal fiscal year.

**Complete Guided Missiles.** PPI data for complete guided missile systems have not been accumulated by the BLS for the 1981 to 1990 period, and finding a definitive proxy is constrained by the limited scope of the PPI data available in the 1981 to 1985 period. Furthermore, PPI data series for the component parts of complete guided missile systems, such as avionics/guidance, airframes, and rocket motors, were not accumulated by the BLS consistently across the entire period. Given that the complete guided missile component of the vectors is the single largest component (representing an average of 26 percent of the individual vectors), several different approaches a: undertaken to find an appropriate proxy for this component. This also allows an assessment of the sensitivity of the overall index to the changes associated with using different proxies for complete guided missiles.

The first proxy used is the PPI for capital equipment, as reported in the *International Financial Statistics Yearbook*.[7] This proxy was selected in that it represents the overall change in prices for production of large-ticket items.

Another approach uses a weighted average of the particular missile components, which are guidance and control equipment, air frame, and propulsion. Because data for these specific series are not available, Electronic Components and Accessories (Consumer Product Code 1178) is used as a proxy for guidance and control systems, while aircraft (SITC Code 3721, see description under "Aircraft" below) is used as a proxy for both the propulsion and air frame components. These were weighted, after consultation with several experts, as guidance and control, 45 percent; propulsion, 10 percent; and air frame, 45 percent. These weights are applied to the component PPI values and a composite PPI value for complete guided missiles is derived.

Another approach employs the PPI data series for aircraft (see discussion below) as a proxy for complete guided missiles.

Finally, the R&D index was also calculated without the complete guided missiles component included in the vector. This has the ef t

[7]International Monetary Fund, Washington, D.C., various years, line 63bb.

of essentially removing the component from Table A.1 and calculating the composite R&D index as if the cost proportion represented thereby is part of "Other Categories."

**Tanks and Tank Components**. PPI data have not been accumulated by the BLS for the SIC Code for Tanks and Tank Components (SIC Code 3795). Accordingly, heavy construction machinery (SIC Code 3531) is used as the proxy. Although this category does not capture the complex electronics and armaments, it is the closest category for which statistics are accumulated.

**Small Arms**. PPI data for the Small Arms category (SIC Code 1513) are available for the entire period. For years before 1985, the PPI was not reported in the general tables, but was provided in the accompanying detailed tables, under the same code.[8]

**Electronic Computing Equipment**. The BLS did not begin to differentiate Electronic Computing Equipment in the PPI tables (SIC Code 3573) until December 1990. Because many of the component parts of modern electronic computing equipment were listed under Electronic Components and Accessories (Consumer Product Code 1178) in the product detail portion of the monthly and annual PPI reports, it was used as a proxy.

**Radio and TV Communication Equipment**. For the period 1985 to 1990, PPI data are accumulated for a category that included the transmission equipment as well as consumer electronics (SIC Code 3662). In the 1981 to 1984 period, however, the transmission equipment was aggregated into a "Secondary Equipment" category and could not be separately identified. For this period, therefore, Electronic Components and Accessories (Consumer Product Code 1178) in the product detail portion of the PPI reports is used as a proxy. In terms of comparability, it is noted that the changes in the PPI for this proxy closely parallel changes in the

[8]The detail tables typically contain price information on individual products and are segregated by Consumer Product Code instead of SIC Code. These codes are typically different for the same category of product, but are organized similarly. In this case, the two codes were the same.

PPI for Radio and TV Communication Equipment during the 1985 to 1990 period.

**Aircraft**. The PPI data for aircraft (SIC Code 3721) are from the general tables for the period 1985 to 1990. These data include information on civilian aircraft only. Before this period, aircraft were not reported in the general tables but were included in the product detail tables under Consumer Product 142, Civilian Aircraft. The two data series appear to mesh together well during the overall period 1981 to 1990.

**Shipbuilding and Repairing**. The PPI series for shipbuilding and repairing (SIC Code 3731), as is the case with the series for aircraft above, include only civilian shipbuilding and repair and are available in the general tables back to 1985 only. The preceding data are from the product detail tables under the Consumer Product Code 3731 and include only civilian activities. As with aircraft, the two trends mesh together well over the period covered in this analysis.

**Engineering and Scientific Equipment**. The PPI data for this series (SIC Code 3811) date back to 1983 only. For the 1981 and 1982 years, no appropriate proxies were available. Subsequently, the PPI for finished goods is applied against the 1983 PPI value to generate an estimated PPI for 1981 and 1982.[9]

**Real Estate**. Real estate represents the first of the service indices in the vector. As discussed above, clear proxies for these services are difficult to find. For the purposes of this analysis, therefore, the CPI for services[10] for urban workers[11] is used as a proxy for this component.

---

[9]For example, the PPI for 1983 was generated by applying the relative change in the PPI for Finished Goods (final consumer-oriented goods) between 1981 and 1983 ($PPI_{1981}/PPI_{1983}$) and multiplying it by the $PPI_{1983}$ for Engineering and Scientific Equipment. A similar operation was performed to obtain the PPI for 1982.

[10]Consumer Price Indices are reported on a monthly and annual basis by the Bureau of Labor Statistics. Values used in this analysis are the annual averages for each year.

[11]The CPI for urban workers is used in this analysis as R&D typically occurs in an urban setting.

**Miscellaneous Business Services**. The CPI for services for urban workers is also used as a proxy for this component.

**Educational Services**. The CPI for Educational and Related Services is used as a proxy for this component series. This information is provided in the detailed sections of the monthly and annual CPI reports and is broken out as an individual subcomponent of the overall CPI for services.

**Non-Profit Organizations**. The CPI for services for urban workers is used as a proxy for this component.

**Employee Compensation**. Price changes in this component are measured by the wage index for manufacturing employees listed in the *International Financial Statistics Yearbook*.[12]

**STEP 3. COMBINING AND AGGREGATING THE DATA**

Now that individual proxy data series for each component of the vectors have been aggregated, the data must be agglomerated into a single index number for each agency. The data are first converted into a common base year. This was done by dividing each index value in a series by the index value for 1985 and multiplying by 100. Please note that although this arithmetically converts each index to a 1985 base year, it does not convert the price structure implicit within each series into a 1985 base year.[13] For purposes of this analysis, these changes are disregarded.

Once the individual series have all been converted into a series that reflects a value of 100.0 for the year 1985, the individual components are weighted by their vector proportion and added together. This weighted total is then normalized to 100 percent (to account for the fact that no index information has been accumulated for the miscellaneous vector components included in "Other Categories") by dividing the weighted aggregate portion by the cumulative total of

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[12]International Monetary Fund, Washington, D.C., various years, line 65ey.

[13]This relates to the fact that the component index series may change over time and that the series themselves reflect the weightings determined in their original base year.

amounts represented in the components included in the analysis.[14] This produces a research and development deflator for each branch of service.

The individual branch composite indices are integrated together to arrive at a combined R&D index. This is done by weighting the branch's index in each year by the branch's proportion[15] of the overall FY 1986 research, development, test, and evaluation appropriation.[16] This detail is provided in Appendix A, Table A.2.

---

[14]For example, if the component sectors included in this analysis made up 90 percent of the total expenditures represented in the vector, then the composite index was divided by 0.9 to normalize it to 100.0.

[15]For purposes of this analysis, the portion of the RDT&E budget for the Director was disregarded. It represents only 0.3 percent of the overall appropriation.

[16]*The Budget for Fiscal Year 1986*, Executive Office of the President, Office of Management and Budget, Washington, D.C., pp. 8-66 to 8-67.

## 3. THE RESEARCH AND DEVELOPMENT DEFLATOR

The resulting research and development indices for each branch as well as the combined R&D index are shown in Appendix A, Tables A.3 to A.6. Each of these tables represents the use of a different proxy for complete guided missiles and displays the derived R&D index values for each branch of service, as well as the composite index.[1]

These individual tables are summarized in Appendix A, Table A.7. This table includes a column labeled "Average," which represents the average of the four estimated R&D deflators. These values are provided as a reference point for the "mid-range" of the four series.

It is interesting to note that the prices within Navy research and development do not change very much,[2] while the Defense Agencies show the greatest changes in prices.[3] Even so, the divergence was not that great, representing only about a 5 percent variance in price levels.

Appendix B, Figure B.1 presents these research and development indices for the four branches plus the composite index for the 1981 to 1990 period for the calculated R&D index using capital goods as the proxy for complete guided missiles. The heavier line represents the combined R&D index values. This figure is provided to show that the indices move closely together over the entire period. Graphic representations of the R&D index series using other proxies for complete guided missile systems would show similar distributions.

Appendix B, Figure B.2 presents the results of the four R&D index series, as distinguished by the proxy used for complete guided missiles. On this figure (and on Figures B.3 and B.4 in Appendix B), the labels have the following meanings: **GNP Deflator**: this is the GNP deflator used for this period; **Capital Goods**: this series represents the resultant R&D index if capital goods are used as a proxy for complete

[1]This composite is based on weighting the individual service R&D indices by their share of the FY 1986 RDT&E appropriation.

[2]This is shown by a comparatively smaller total change in its R&D index over the ten-year period of only 32.2 index points.

[3]This is shown by a comparatively larger change in its R&D index over the ten-year period of 36.8 index points.

guided missiles; **Electronics and Aircraft**: this series is the resulting R&D index when a weighted composite of a guided missile's component parts is used as a proxy for complete guided missiles; **Aircraft Only**: this is the resultant series if aircraft alone are used as the proxy for complete guided missiles; and **Excluding Missiles**: this is the resultant series if complete guided missiles are treated as "Other Categories" and no proxy is used in the index.

Figures B.3 and B.4 (in Appendix B) present the information in greater resolution, using 1985 as a breaking point to separate Appendix B, Figure B.2 into two figures. Note that the scales on the y-axes change between Figures B.3 and B.4.

Returning to Table A.7 (Appendix A), it is useful to consider the variability of the several derived R&D indices with respect to the deflator now in use, the GNP deflator. It is interesting to note that the R&D indices tend to approximate the value to the GNP deflator, the series for which they are developed to replace. The GNP deflator changes by 33.7 points over the period 1981 to 1990, whereas the most variable R&D index changes 37.7 points, a difference of about 0.5 percent in the annual change in prices captured in the series over the ten-year period.[4] This small amount could be significant, however, when one is applying it to billions of dollars.

By and large, however, the differences are not that large, especially when weighed against the potential costs and ramifications of making exceptions. One can conclude that the current approach of using the GNP deflator to value expenditure flows over time, insofar as the methods used in this study accurately reflect or approximate the price changes associated with the research and development activity, is an appropriate process and that, as long as this type of price index is considered the appropriate tool for valuing these streams, the GNP deflator is a representative index for research and development activities.

[4]This is calculated in two steps. First, divide the difference in the spreads (4.0 points) by the initial GNP deflator value of 84.8, yielding a value of 0.0472. Then add 1.0 to this number and take the tenth-root to arrive at the geometric mean for the ten-year period.

## Appendix A

## TABLES

**Table A.1**
**Branch Vectors by Component**
**(in percentages)**

| Component Sectors | Army Vector | Navy Vector | Air Force Vector | Defense Agencies Vector |
|---|---|---|---|---|
| Complete guided missiles | 17.2671 | 37.38622 | 29.7600 | 20.5067 |
| Tanks and tank components | 4.3981 | | | |
| Small arms | | 4.31537 | | |
| Electronic computing equipment | | | | 3.4277 |
| Radio & TV communication equipment | 20.2466 | 9.55884 | 20.5302 | 21.3568 |
| Aircraft | 4.3792 | 5.54528 | 9.9717 | 5.1710 |
| Shipbuilding and repairing | | 3.31028 | | |
| Engineering and scientific equipment | | | 5.6815 | |
| Real estate | | | 4.1493 | |
| Misc. business services | 17.6741 | 5.12463 | 11.7838 | 20.7926 |
| Educational services | 7.2271 | 4.32656 | 4.7974 | 8.8931 |
| Non-profit organizations | | 4.21174 | | 3.4258 |
| Employee compensation | 11.7499 | 23.13066 | 5.1467 | 3.9316 |
| Other categories | 17.0579 | 3.09042 | 18.1511 | 12.4947 |
| VECTOR TOTALS | 100.0000 | 100.00000 | 100.0000 | 100.0000 |

SOURCE: Thomas P. Frazier, Carol G. Campbell, and Richard T. Cheslow. *The Revised Defense Translator*, IDA Paper P-2141, Institute for Defense Analysis, Alexandria, Virginia, October 1989, pp. VI-4 to VI-9.

**Table A.2**

**Research, Development, Testing and Evaluation Appropriation for Fiscal Year 1986**

| Branch | Appropriation | Percentage[a] |
|---|---|---|
| Army | $ 5,279,900,000 | 13.5 |
| Navy | 11,264,300,000 | 28.7 |
| Air Force | 15,578,500,000 | 39.8 |
| Defense Agencies | 7,053,900,000 | 18.0 |
| Office of the Director | 103,500,000 | 0.0 |
| TOTAL | $39,280,100,000 | 100.0 |

SOURCE: *The Budget for Fiscal Year 1986*, Executive Office of the President, Office of Management and Budget, Washington, D.C., pp. 8-66 to 8-67.

[a]Percentages are calculated excluding the appropriation for the Office of the Director.

**Table A.3**

**Individual and Composite Research and Development Indices Using Capital Goods as a Proxy for Complete Guided Missile Systems**

| | Army | Navy | Air Force | Defense Agencies | Combined |
|---|---|---|---|---|---|
| 1981 | 84.3 | 85.3 | 84.9 | 84.0 | 84.7 |
| 1982 | 89.2 | 90.1 | 89.7 | 88.9 | 89.6 |
| 1983 | 93.2 | 93.7 | 93.7 | 93.2 | 93.5 |
| 1984 | 96.8 | 96.9 | 97.0 | 96.8 | 96.9 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 103.9 | 102.9 | 103.2 | 104.5 | 103.4 |
| 1987 | 106.4 | 105.2 | 105.4 | 107.2 | 105.8 |
| 1988 | 110.1 | 108.5 | 108.5 | 111.2 | 109.2 |
| 1989 | 114.8 | 113.1 | 113.3 | 116.1 | 113.9 |
| 1990 | 119.4 | 117.5 | 117.7 | 120.8 | 118.4 |

**Table A.4**

**Individual and Composite Research and Development Indices Using a Weighted Average of Electronic Components and Aircraft as a Proxy for Complete Guided Missile Systems**

| | Army | Navy | Air Force | Defense Agencies | Combined |
|---|---|---|---|---|---|
| 1981 | 82.9 | 82.5 | 82.6 | 82.3 | 82.6 |
| 1982 | 87.7 | 87.3 | 87.4 | 87.2 | 87.4 |
| 1983 | 92.6 | 92.4 | 92.7 | 92.4 | 92.6 |
| 1984 | 96.5 | 96.4 | 96.6 | 96.5 | 96.5 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 103.6 | 102.5 | 102.8 | 104.2 | 103.1 |
| 1987 | 105.7 | 104.0 | 104.3 | 106.5 | 104.8 |
| 1988 | 109.4 | 107.2 | 107.5 | 110.4 | 108.2 |
| 1989 | 114.3 | 112.3 | 112.6 | 115.6 | 113.3 |
| 1990 | 118.9 | 116.4 | 116.8 | 120.2 | 117.5 |

**Table A.5**

**Individual and Composite Research and Development Indices Using Aircraft as a Proxy for Complete Guided Missile Systems**

| | Army | Navy | Air Force | Defense Agencies | Combined |
|---|---|---|---|---|---|
| 1981 | 82.0 | 80.9 | 81.3 | 81.3 | 81.3 |
| 1982 | 87.1 | 86.2 | 86.5 | 86.5 | 86.5 |
| 1983 | 92.2 | 91.8 | 92.1 | 92.0 | 92.0 |
| 1984 | 96.3 | 96.1 | 96.3 | 96.3 | 96.2 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 103.4 | 102.1 | 102.5 | 104.0 | 102.8 |
| 1987 | 105.4 | 103.4 | 103.8 | 106.1 | 104.3 |
| 1988 | 109.1 | 106.6 | 107.0 | 110.1 | 107.7 |
| 1989 | 114.7 | 112.9 | 113.2 | 116.0 | 113.8 |
| 1990 | 119.8 | 118.2 | 118.3 | 121.3 | 119.0 |

**Table A.6**

**Individual and Composite Research and Development Indices Omitting Complete Guided Missile Systems**

| | Army | Navy | Air Force | Defense Agencies | Combined |
|---|---|---|---|---|---|
| 1981 | 83.4 | 83.5 | 83.4 | 82.7 | 83.3 |
| 1982 | 88.2 | 88.3 | 88.1 | 87.6 | 88.1 |
| 1983 | 92.6 | 92.4 | 92.9 | 92.4 | 92.6 |
| 1984 | 96.5 | 96.3 | 96.7 | 96.5 | 96.5 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 104.3 | 103.5 | 103.8 | 105.2 | 104.1 |
| 1987 | 107.0 | 106.1 | 106.1 | 108.2 | 106.6 |
| 1988 | 111.1 | 109.9 | 109.6 | 112.7 | 110.5 |
| 1989 | 115.9 | 114.7 | 114.6 | 117.8 | 115.4 |
| 1990 | 120.8 | 119.5 | 119.4 | 122.9 | 120.3 |

**Table A.7**

**Summary of Results of Composite Indices**

| | GNP Deflator | Capital Goods Proxy for CGM[a] | Electronic Components and Aircraft Proxy for CGM | Aircraft Proxy for CGM | CGM Omitted | Average |
|---|---|---|---|---|---|---|
| 1981 | 84.8 | 84.7 | 82.6 | 81.3 | 83.3 | 83.0 |
| 1982 | 90.2 | 89.6 | 87.4 | 86.5 | 88.1 | 87.9 |
| 1983 | 93.7 | 93.5 | 92.6 | 92.0 | 92.6 | 92.7 |
| 1984 | 97.1 | 96.9 | 96.5 | 96.2 | 96.5 | 96.6 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 102.6 | 103.4 | 103.1 | 102.8 | 104.1 | 103.3 |
| 1987 | 105.9 | 105.8 | 104.8 | 104.3 | 106.6 | 105.4 |
| 1988 | 109.4 | 109.2 | 108.2 | 107.7 | 110.5 | 108.9 |
| 1989 | 113.9 | 113.9 | 113.3 | 113.8 | 115.4 | 114.1 |
| 1990 | 118.5 | 118.4 | 117.5 | 119.0 | 120.3 | 118.8 |

SOURCE: GNP deflator is from the Council of Economic Advisors, *Economic Indicators*, U.S. Government Printing Office, Washington, D.C., various years.

[a]CGM stands for Complete Guided Missiles.

**Table A.8**

**A Comparison of Several Indices**

| | Average R&D Index | CPI | PPI | GNP Deflator |
|---|---|---|---|---|
| 1981 | 83.0 | 84.5 | 95.0 | 84.8 |
| 1982 | 87.9 | 89.7 | 96.9 | 90.2 |
| 1983 | 92.7 | 92.6 | 98.1 | 93.7 |
| 1984 | 96.6 | 96.6 | 100.5 | 97.1 |
| 1985 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1986 | 103.3 | 101.9 | 97.1 | 102.6 |
| 1987 | 105.4 | 105.7 | 99.7 | 105.9 |
| 1988 | 108.9 | 109.9 | 103.7 | 109.4 |
| 1989 | 114.1 | 115.2 | 108.8 | 113.9 |
| 1990 | 118.8 | 121.4 | 112.7 | 118.5 |

SOURCE: Average R&D Index: This analysis; CPI, PPI: International Monetary Fund, *International Financial Statistics Yearbook*, various years (CPI: line 64; PPI: line 63); GNP deflator: Council of Economic Advisors, *Economic Indicators*, U.S. Government Printing Office, Washington, D.C., various years.

## Appendix B

## FIGURES

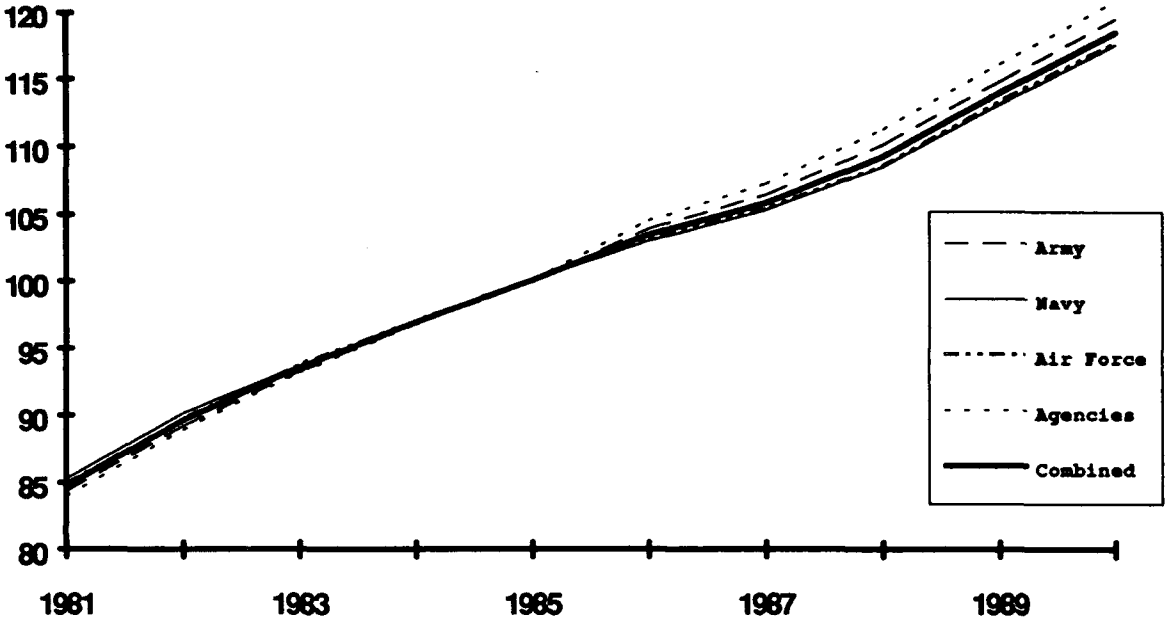


Figure B.1-Research and Development Indices for 1981 to 1990 Using Capital Equipment as Proxy for Complete Guided Missiles

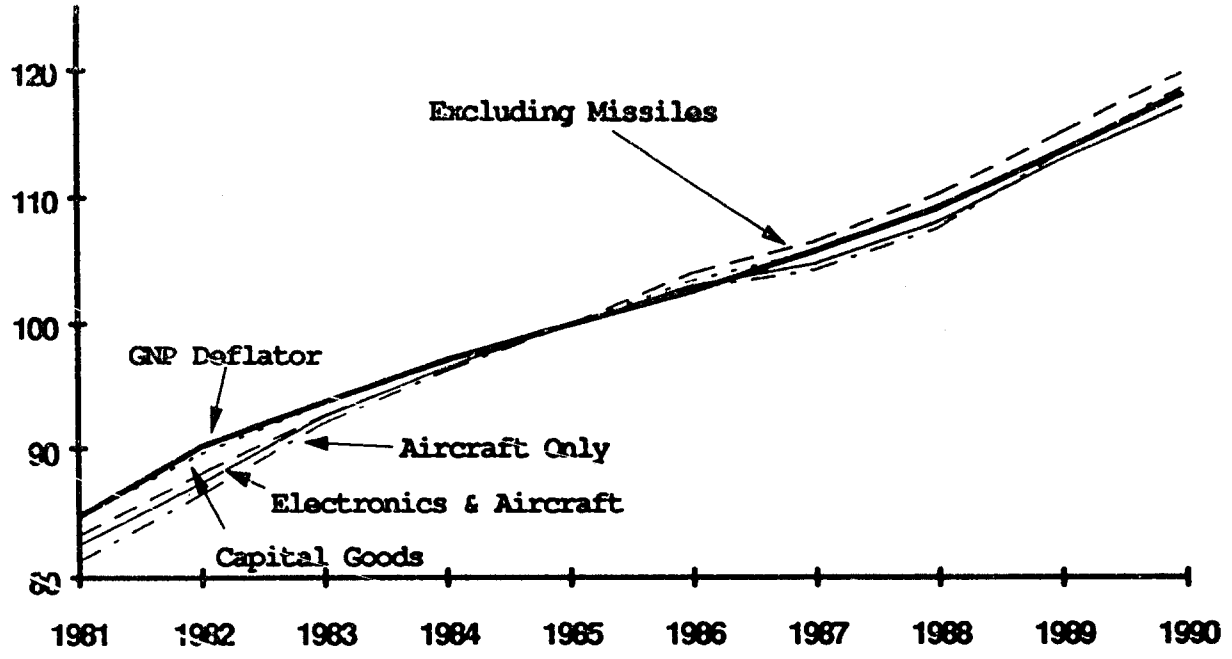


Figure B.2-Research and Development Indices for 1981 to 1990 Using Alternative Proxies for Complete Guided Missiles

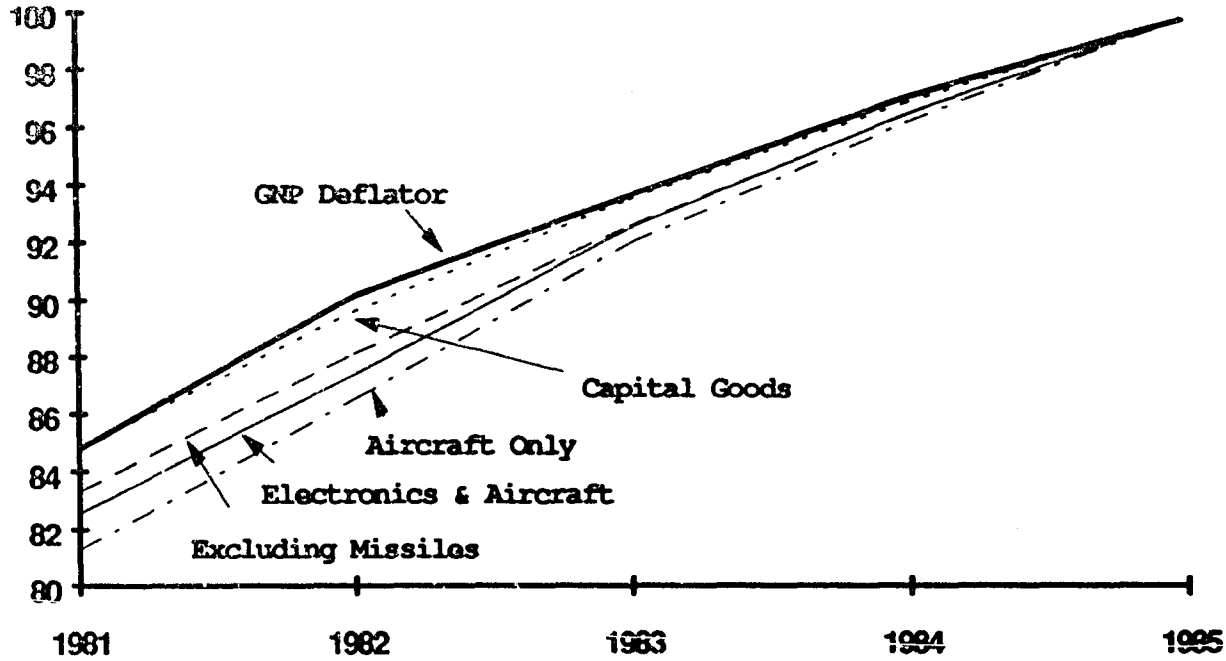


Figure B.3-Research and Development Indices for 1981 to 1985 Using Alternative Proxies for Complete Guidad Missiles

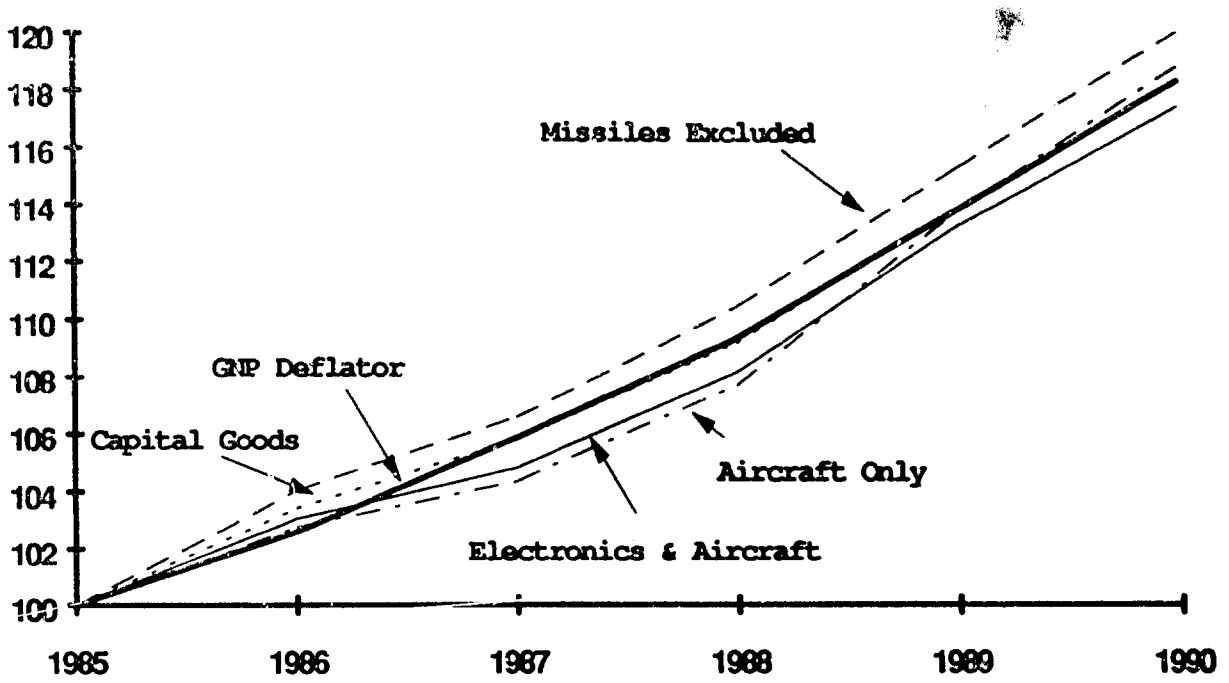


Figure B.4-Research and Development Indices for 1985 to 1990 Using Alternative Proxies for Complete Guided Missiles